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FARMERS' BULLETIN
No. 1890

CONTROL OF INSECTS AND MITES attacking NARCISSUS BULBS

UNITED STATES DEPARTMENT OF AGRICULTURE

THE NARCISSUS BULB FLY is responsible for the destruction of large quantities of bulbs throughout the narcissus-growing areas of the United States. The lesser bulb flies and two species of mites also cause more or less damage. This bulletin contains descriptions of these pests and information concerning their life histories and habits and the nature of their attacks on bulbs.

Fortunately several effective methods for controlling these pests are available. Control measures are also described in this bulletin. Whenever an infestation by one or more of the pests is detected, use of the appropriate control method will aid the grower in the production of narcissus bulbs of good quality.

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CONTROL OF INSECTS AND MITES ATTACKING NARCISSUS BULBS

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PREVENTING attacks of insects and mites on narcissus bulbs has been a major problem confronting commercial growers in their efforts to produce bulbs of the best quality for sale. Gardeners also have been concerned at times because of the depredations of these pests. The principal pests causing damage are the narcissus bulb fly, the lesser bulb flies, the bulb mite, and the bulb scale mite. All these are generally present in areas where narcissus bulbs are produced, and, with certain climatic limitations, they may be encountered wherever narcissus bulbs are grown in gardens. Methods of elimination or control have been developed that will reduce damage appreciably, thereby improving the general quality of the bulbs and saving many bulbs that would otherwise be destroyed.

THE NARCISSUS BULB FLY

The narcissus bulb fly (*Merodon equestris* (F.)) is usually considered the most important insect attacking narcissus bulbs. This fly, thought to have been a native of southern Europe, appeared in the bulb areas of northern Europe early in the nineteenth century. It has been reported as present in the United States as early as 1879 and in Canada in 1903. The fly is now definitely established in the major narcissus-producing sections of the United States.

DESCRIPTION OF THE STAGES

It is the larval stage, or grub, that is almost always encountered by growers, although, of course, the insect goes through the usual developmental stages—egg, larva, pupa, and adult. The eggs are white, elongate oval, with slight reticulations of the surface visible through the microscope; they are about one-sixteenth of an inch long and not too small for the careful observer to locate on narcissus leaves just at or below the surface of the ground (fig. 1).

When hatched, the larva is one-fifteenth of an inch long. As it develops, it sheds its skin twice and when full grown has a length

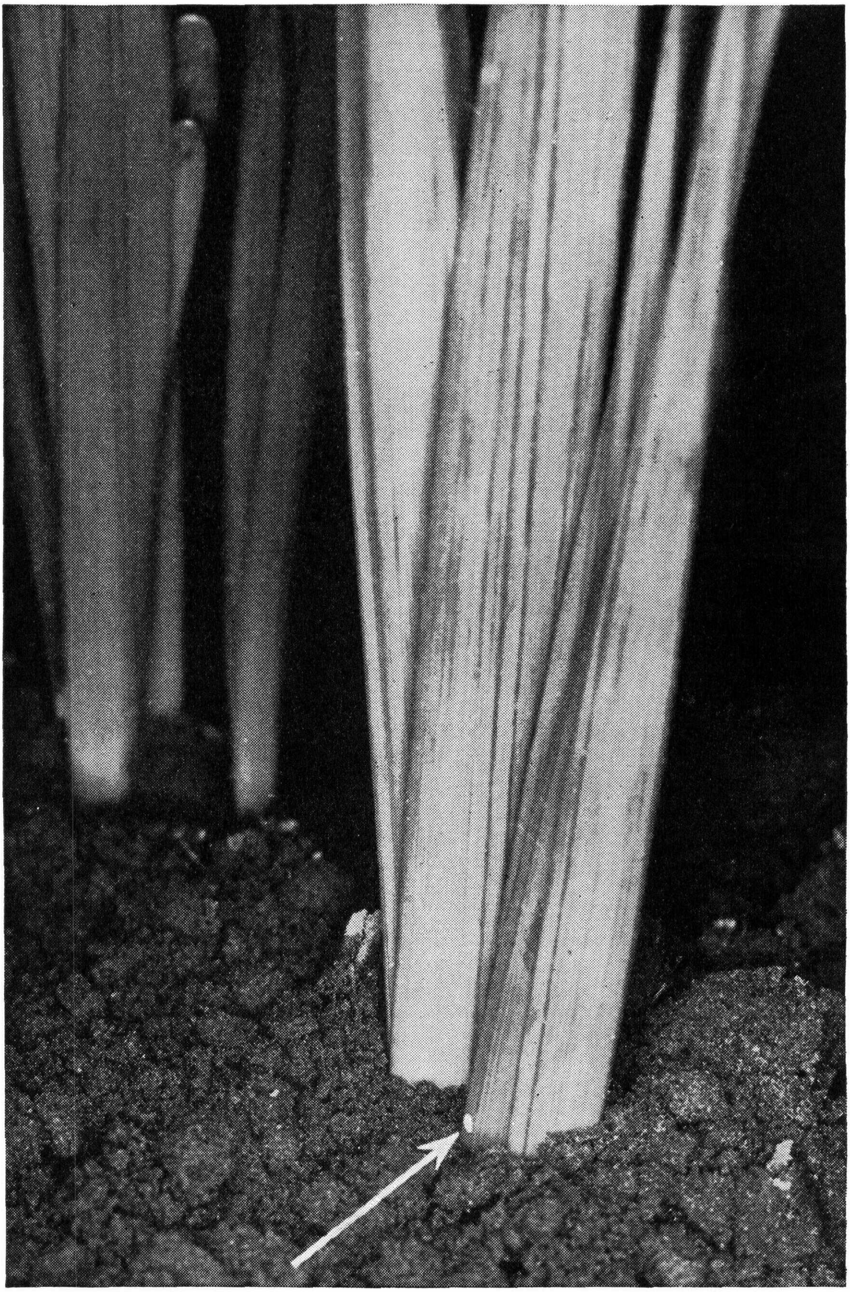

FIGURE 1.—An egg of the narcissus bulb fly on a narcissus leaf just above the surface of the ground.

of five-eighths to three-fourths of an inch. Very shortly after hatching, it enters the bulb and does not leave it till time for pupation. The mature larva has a slightly arched body with a tough, distinctly wrinkled skin, and is plump and nearly circular in cross section.

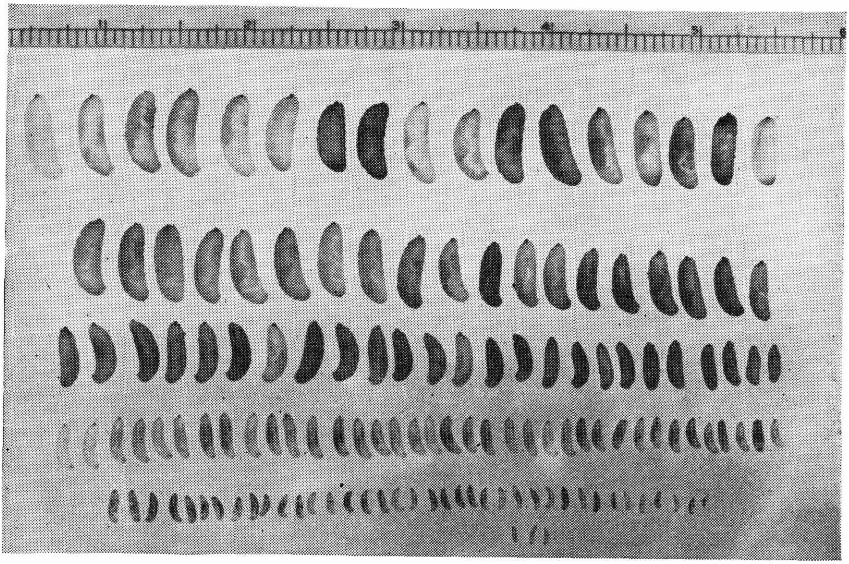

FIGURE 2.—These 139 narcissus bulb fly larvae were removed from 500 bulbs from one planting on September 3, 1936.

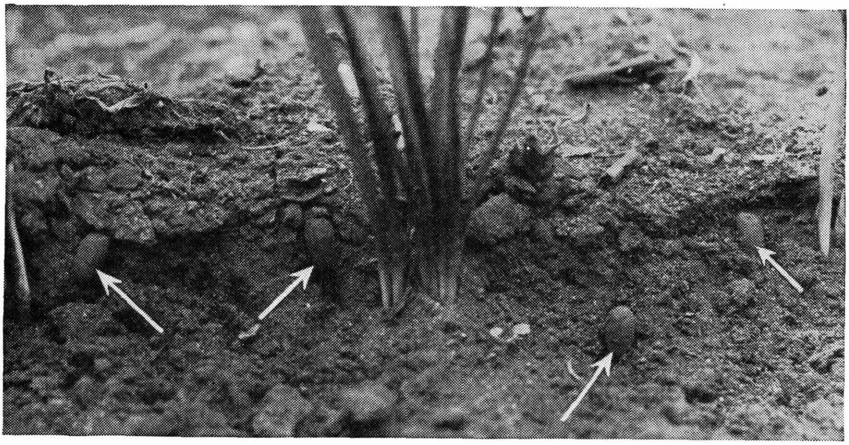

FIGURE 3.—Soil has been moved away to reveal narcissus bulb fly puparia located just below the surface of the soil.

The breathing tube at the hind end is conspicuous because its almost-black color contrasts strongly with the light dirty-tan body. The head is slightly tapered and bears the black mouth hooks that are used to tear the bulb tissue. When handled, the grub contracts its body; and if the mouth hooks are touched, it quickly draws them

in almost out of sight. The sluggish habit of the grubs makes it difficult at times to determine whether they are alive or not, but a light touch on the mouth hooks furnishes a quick and reliable test of life. All stages of the larva are shown in figure 2.

There are no other forms of larvae with which the older larvae of the narcissus bulb fly ordinarily might be confused. The younger larvae are somewhat similar to the larvae of the lesser bulb flies but may be distinguished by the posterior breathing tube, which is dark-colored and stubby, while in the lesser bulb fly larvae it is brick red

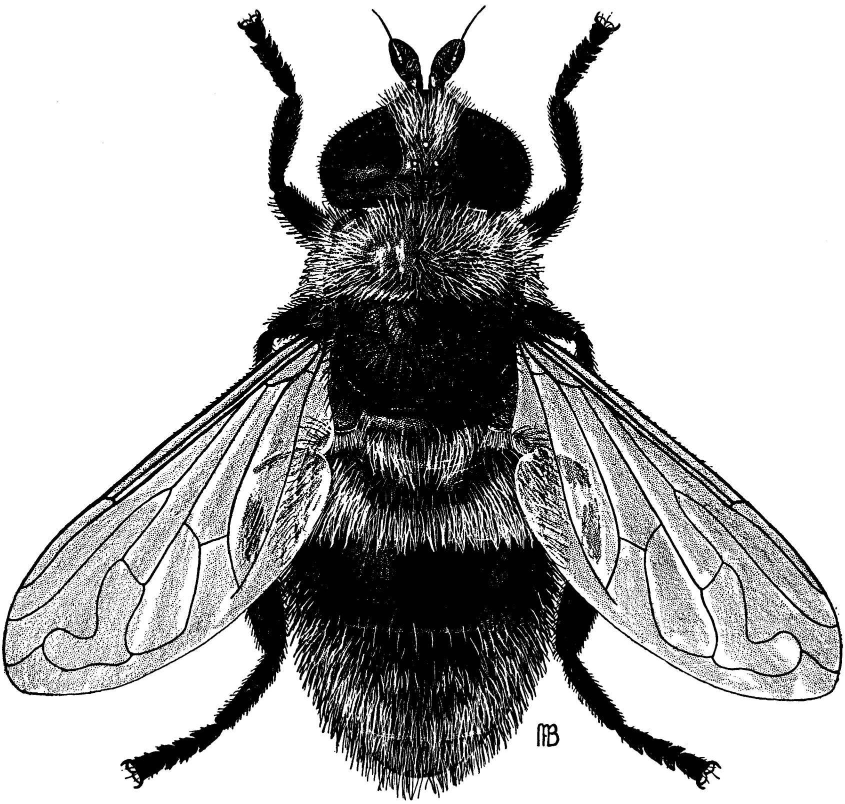

FIGURE 4.—Adult female narcissus bulb fly. About 6 times natural size.

and distinctly more elongate. Also, the younger narcissus bulb fly larvae always work singly and are to be found in distinct tunnels or burrows in the bulb, whereas the lesser bulb fly larvae work in groups, and the injured bulb tissue is a homogeneous mass, usually quite wet.

The pupa is a transitional stage during which the insect changes from the grub, or larva, to the adult fly. The larvae leave the bulbs and move upward through the soil to the surface, where they pupate (fig. 3). The skin of the mature larva hardens to form the covering, or puparium, under which the transformation occurs. The pupa therefore very much resembles the larva except that it is hard instead

of elastic and yielding. The ends of the pupa are also much more rounded than those of the larva. The breathing tube of the larva is quite evident in the pupa, but it is not so conspicuous because the pupa is a darker gray brown. Several days after the start of the pupal stage two breathing tubes resembling horns emerge on the upper side of the pupa toward the front. Pupae may be found by carefully examining the soil over bulbs showing symptoms of infestation.

The adult two-winged fly (fig. 4) is approximately half an inch long. In coloration and general appearance it very much resembles a small bumblebee. The apparent color of the fly is that of the long hairs that cover the black body. Various combinations of black, yellow, orange, and buff bands of hairs on the thorax and abdomen result in a considerable variation of the general color pattern.

SEASONAL DEVELOPMENTAL HISTORY

In its normal development the narcissus bulb fly passes the winter as a mature larva in a bulb. Early in the spring the overwintering larva leaves the bulb and moves to the soil surface, where it changes to a pupa. This migration and pupation extend through March and into April. Emergence of adults begins late in April and extends into June. The peak of adult activity is in mid-May. The females deposit eggs singly on the bulb foliage approximately at the ground level, and occasionally in the soil close to the bulb foliage. Following the surface of the bulb, the newly hatched maggot moves downward through the soil to the base of the bulb, where it enters, starts feeding, and proceeds through its development during the summer and fall, remaining in an inactive condition in the bulbs through the winter. The normal life cycle is completed in 1 year. Under certain conditions in some localities the development of a few of the larvae is retarded during the summer, and these remain comparatively small until the following spring. Resuming activity then, these larvae feed and develop rapidly during the spring and summer, pass the second winter as mature larvae, and pupate and emerge as adults the second spring. Where this retardation has been noted the proportion of the grubs involved has usually been low, seldom more than 5 percent of the population. Both normal and retarded development are presented diagrammatically in figure 5.

NATURE AND EXTENT OF ATTACK

Immediately after hatching, the grub moves downward to the base of the bulb and enters close to a root. By rasping and tearing with its mouth hook, it tunnels back and forth in the basal-plate tissue for several weeks (fig. 6) and then moves upward into the scales (fig. 7, *A* and *B*). The tunnel that is formed is very distinct, for the bulb tissue surrounding it turns brown. The tunnel is enlarged to accommodate the growing grub, and soon after the larva is about half-grown the tunnel becomes a more or less general, gouged-out area of the bulb (fig. 7, *C*). Smaller bulbs are usually completely destroyed, and larger ones are seriously injured. The base of a bulb is its growth center, and much of this tissue is killed by the feeding of the larva in its early stages. In large bulbs sufficient basal-plate tissue usually

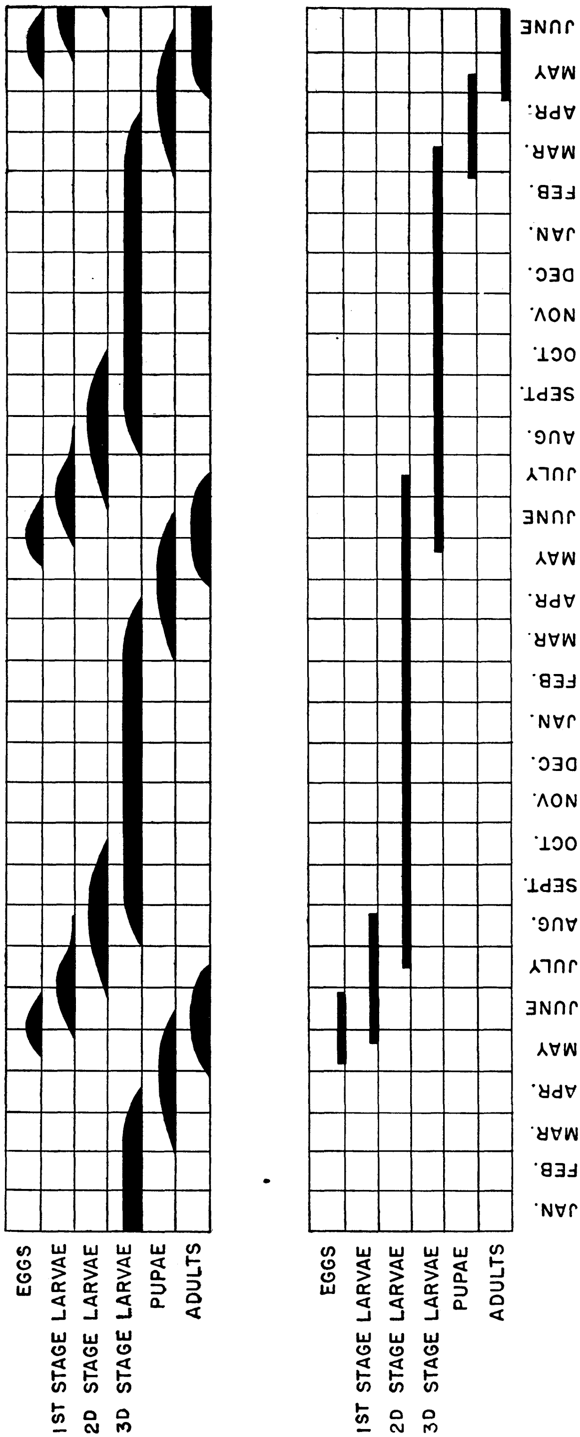

FIGURE 5.—Diagram of the seasonal development of the various stages of the narcissus bulb fly. The upper chart presents the normal development which proceeds through one generation a year, and the lower chart shows the retardation which causes a few individuals to require 2 years for development.

remains uninjured to allow the bulb to make some growth, but this does not return to normal before 2 or 3 years. Often the central area of a bulb is destroyed, and several small bulbs develop around the undamaged edges of the plate area, but these small bulbs do not reach normal size for at least 2 years.

Infestation in growing bulbs is indicated by lack of foliage. If the bulb is not too seriously damaged, it may produce a few leaves. These are usually rather small and grassy in nature (fig. 8). Before they are planted, infested bulbs may be detected by examining the bases.

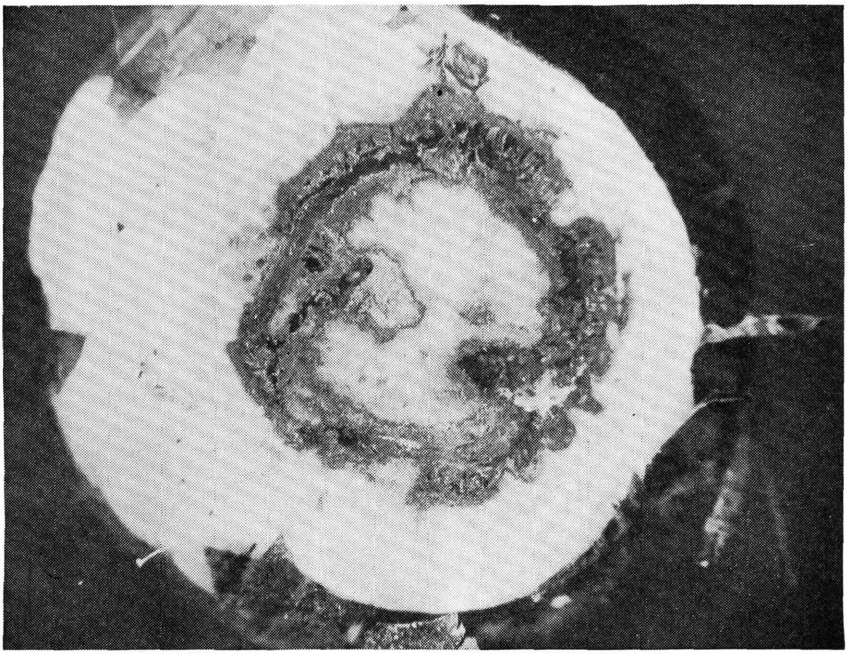

FIGURE 6.—After the maggot enters the base of the narcissus bulb it tunnels around in the basal area for several weeks, as is shown in this bulb from which part of the base has been cut.

Cleaning soil and old roots away with a small, stiff hand brush or scraping with a knife aids in this examination. Infestation is indicated by a brown-colored, sunken portion of the root ring which surrounds the base (fig. 9). The deep-brown discoloration often extends upward on the side of the bulb above the point of attack.

The rate of infestation varies considerably. It is usually very high in garden plantings, where a 75-percent infestation has been recorded. In commercial plantings usually from 2 to 10 percent of the bulbs are infested, some varieties being more susceptible than others. A thorough survey in 1938 indicated that infested bulbs in commercial plantings in Oregon and Washington represented a value of at least $75,000.

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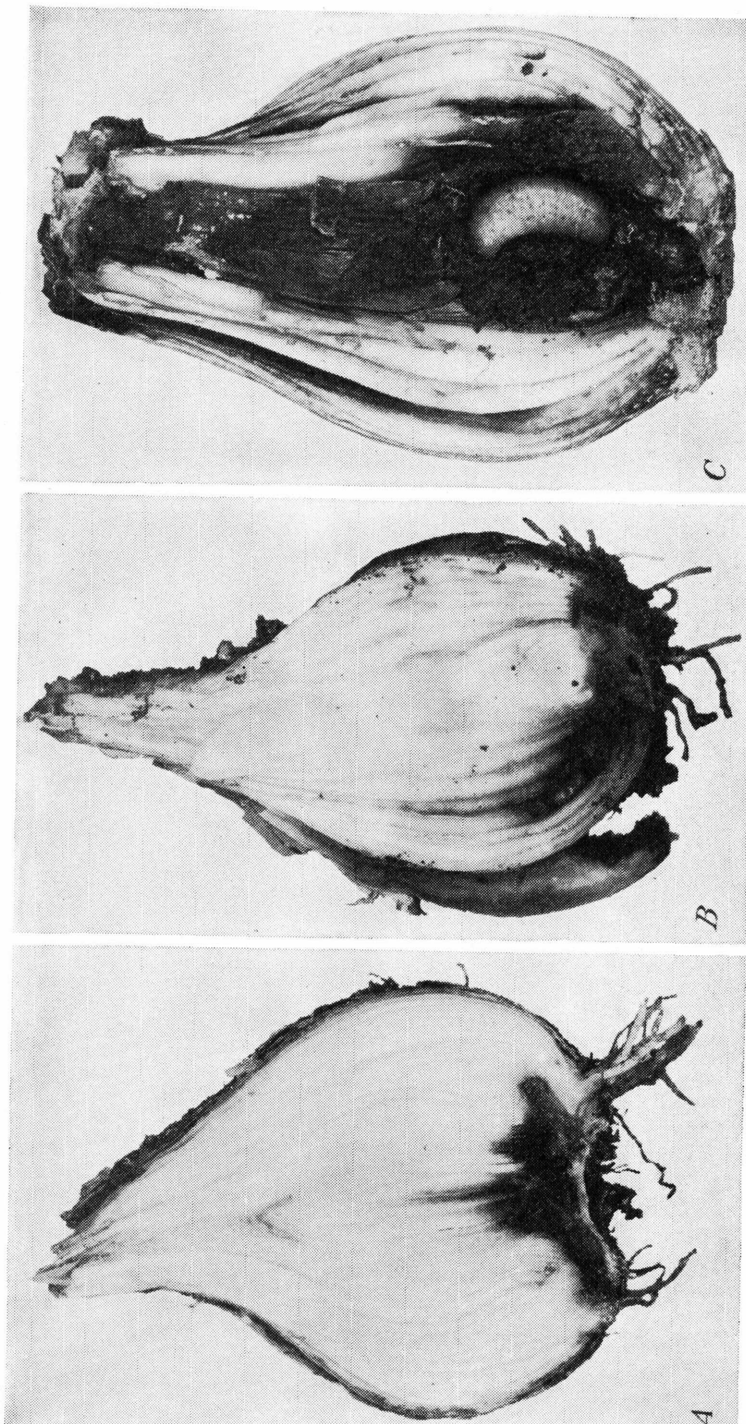

FIGURE 7.—Three stages in the destruction of a bulb by the narcissus bulb fly: *A*, The basal portion of the bulb is seriously injured by the feeding of the maggot in its early stages; *B*, after feeding for several weeks in the basal portion of the bulb the maggot moves upward into the scale tissue; *C*, by the time the maggot has become full-grown it has gouged out a large portion of the center of the bulb.

FIGURE 8.—Single leaves usually indicate that the bulbs from which they are developing have been practically destroyed by narcissus bulb fly maggots.

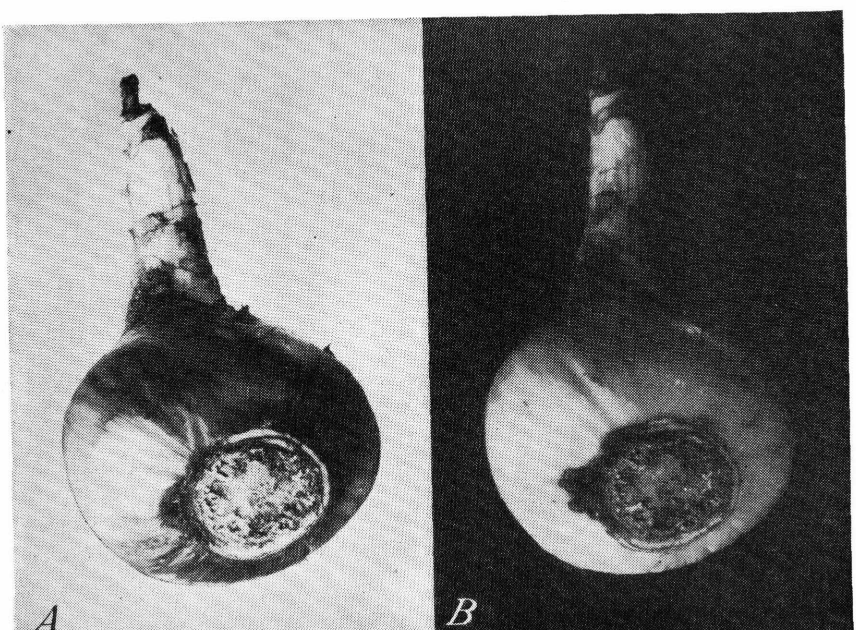

FIGURE 9.—*A*, a sunken, dark-colored portion of the edge of the basal plate of a narcissus bulb indicates that the bulb is infested with a narcissus bulb fly maggot; *B*, if the outer dried scales are removed, the discoloration will be found to extend into the living scale tissue.

HABITS

The narcissus bulb fly larva spends its entire developmental period within a bulb. It moves to the bulb shortly after hatching and from the bulb to the soil surface just previous to pupation. Occasionally a maggot consumes all the tissue of a small bulb before reaching maturity and leaves that bulb and wanders through the soil in search of another bulb in which to complete its development.

The adults are active fliers and prefer sunny conditions. They feed on pollen and nectar from flowers and leave narcissus plantings in search of this food. They return to narcissus plantings to deposit eggs, and as a consequence of this movement bulb infestation is distinctly greater around the outer borders of a planting. In the bulb field the flies may be observed resting on narcissus leaves or earth clods, but they fly off when disturbed. Flight among the plants is somewhat zig-zag and usually along the rows or among the leaves, about 8 to 10 inches above the ground. If disturbed two or three times, a fly darts upward into the air and is quickly out of sight. A peculiar high-pitched hum characteristic of the flies may be heard at times in the field when they are most active during warm, sunny weather. Because of a dislike for wind they are more likely to be found where there is shelter; consequently narcissus plantings in open fields subject to the full sweep of winds usually have light infestation. Cool, foggy, cloudy, or rainy weather causes almost complete cessation of fly activities.

THE LESSER BULB FLIES

Occasionally narcissus bulbs are found which are more or less rotted and contain numbers of moderately active maggots in the decayed tissue (fig. 10). These are larvae of the lesser bulb flies. Three distinct species occur in narcissus bulbs, of which *Eumerus tuberculatus* Rond. is generally predominant, *Eumerus strigatus* Fallen is occasionally found, and *Eumerus narcissi* Smith is present in limited numbers only in a few localities, as far as known. However, as the general appearance and habits of all three are quite similar, they are discussed as a group.

Various opinions have been presented concerning the nature of the feeding of these insects in bulbs. Claims have been made that the larvae are not able to infest normal, sound narcissus bulbs, that they are able to enter only bulbs in which decay or rot has already affected the tissue. It is known that the larvae of the lesser bulb flies are not able to develop in the absence of certain decay organisms. There is no doubt, however, that many bulbs in which decay or injury may be only incipient could be saved if larvae of the lesser bulb fly could be prevented from attacking them, and from this viewpoint, at least, these insects may be considered as economically injurious.

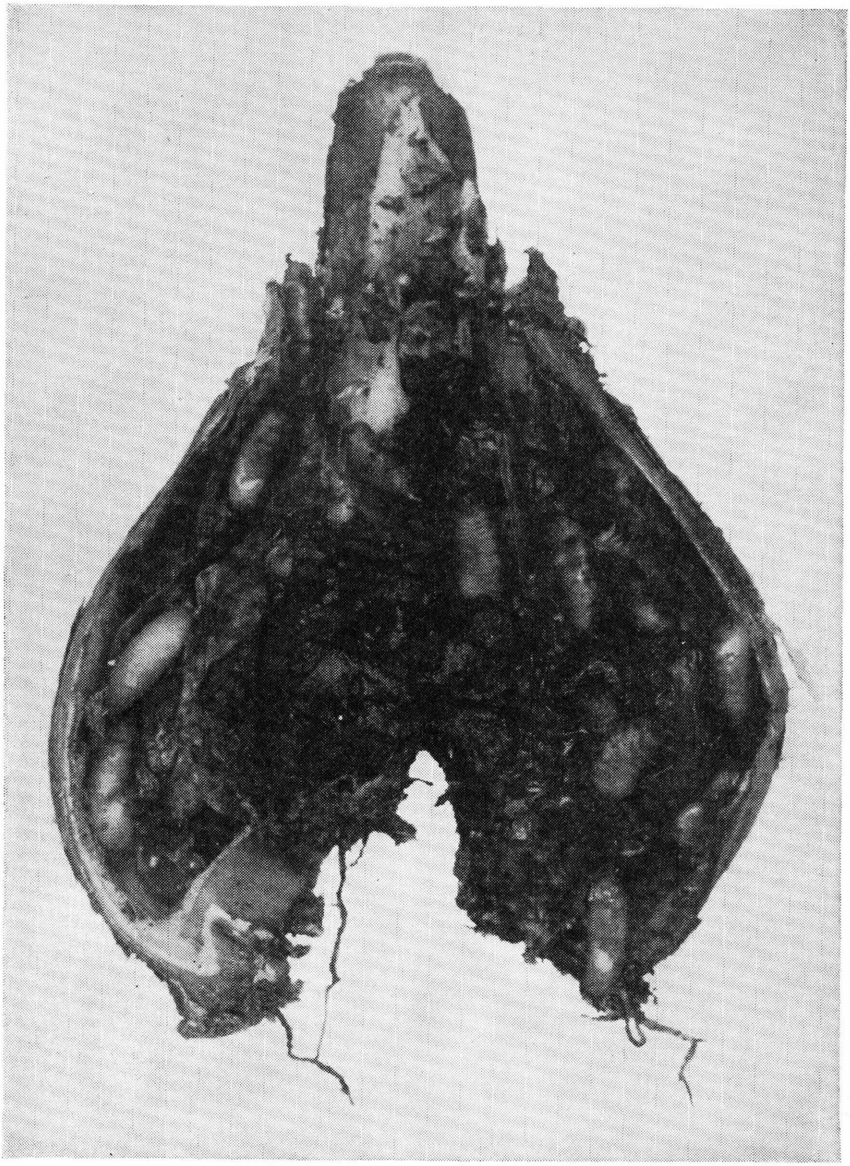

FIGURE 10.—Lesser bulb fly maggots in a rotted narcissus bulb.

DESCRIPTION OF THE STAGES

The chalk-white eggs are about one thirty-fifth inch long and one-third as wide. One end is somewhat bluntly rounded, and the other is noticeably tapered. The eggs are usually deposited in groups of 3 to 10 in the soil close to the necks of the bulbs or on the leaves of the bulb just below the surface (fig. 11).

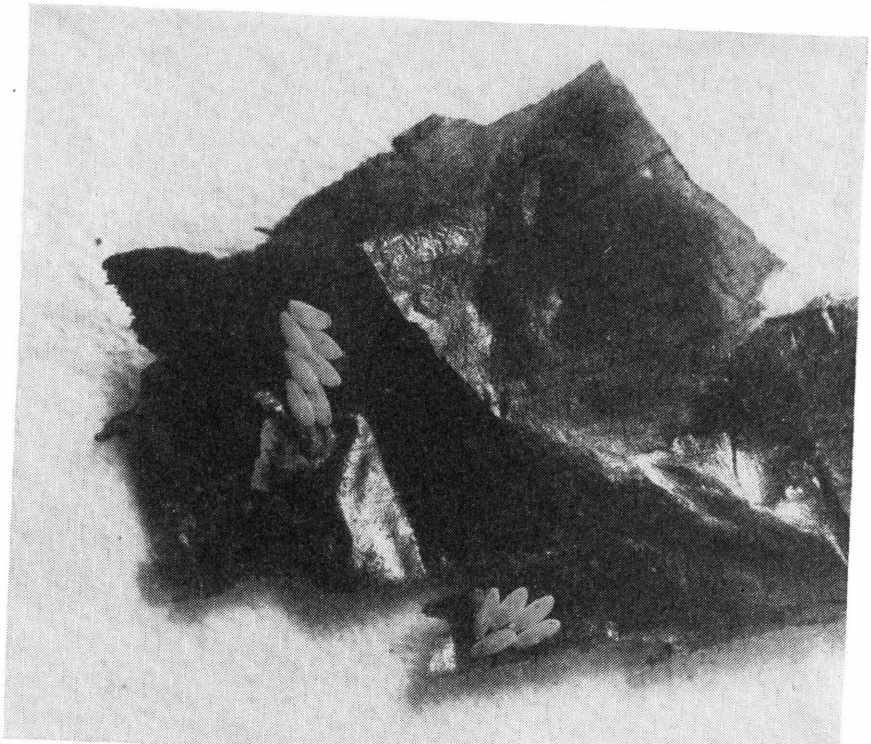

FIGURE 11.—Eggs of a lesser bulb fly (*Eumerus tuberculatus*). About 9 times natural size.

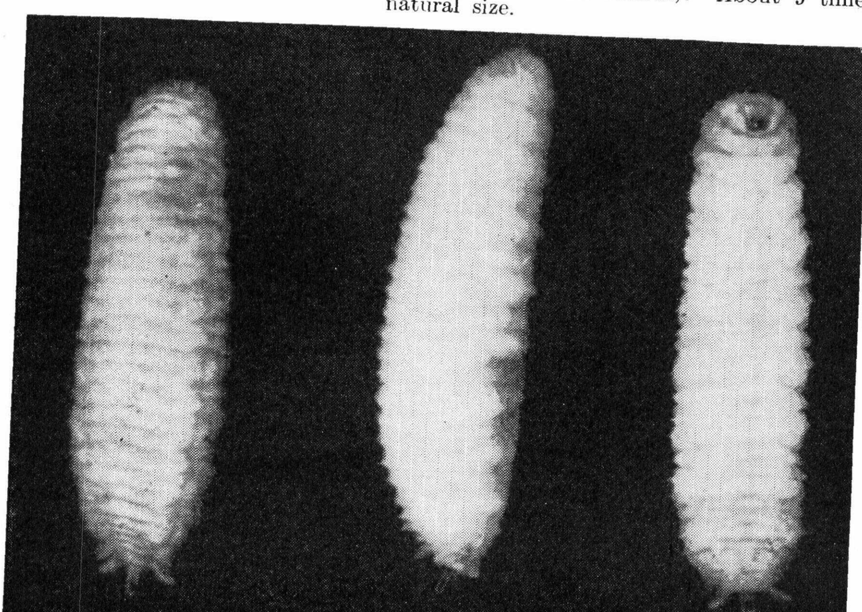

FIGURE 12.—Larvae of a lesser bulb fly (*Eumerus tuberculatus*). About 6 times natural size.

The larvae, or maggots (fig. 12), are the forms which are most often seen, and are always in the bulbs, where they live in moist decaying tissue. Ordinarily from 20 to 50 larvae are present together in a bulb. Their apparent color is a dirty brownish yellow, which is largely due to staining from the rotted tissue in which they live. A pair of elongate, pale-yellowish internal organs are noticeable. These larvae are rather slender and slightly flattened. Having no legs, they depend on body undulations to move around. They are active and squirm about. At the hind end there is a conspicuous, projecting, brick-red

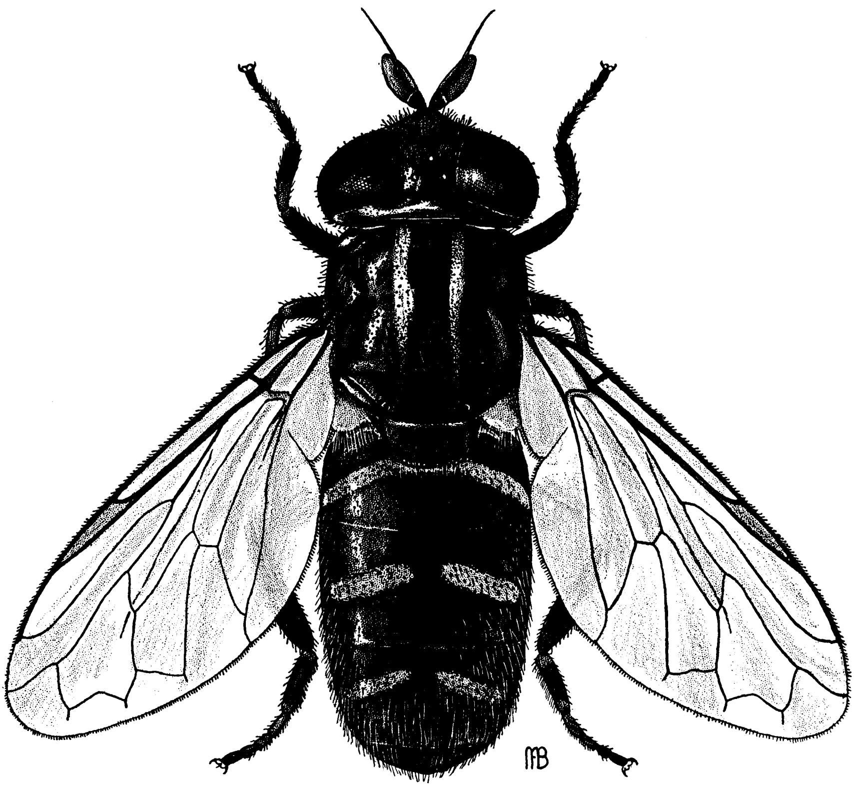

FIGURE 13.—Adult of one of the lesser bulb flies, *Eumerus tuberculatus*. About 12 times natural size.

tube, which is part of the respiratory system, and also extending from the hind end of the body are two prominent tapering tubercles, one on each side of the respiratory tube and about one-third its length. These three posterior projections are characteristic of the lesser bulb fly larvae and serve to identify them. Mature larvae are about three-eighths of an inch long.

The skin of the mature larva forms the shell within which the transformation to the adult fly takes place. There is some contraction of the head end, which assumes a broad rounded form, giving the pupa a general pear shape, with the conspicuous breathing tube forming the apparent stem. A few days after pupation begins two hornlike spines

appear on the upper part of the rounded front of the pupa. These are part of the respiratory system. The pupa is a dull dark-brownish gray.

The adult flies appear black at a distance, but closer examination reveals the color to be a dark blue with suffused iridescence. There are three pairs of grayish-white marks on the upper side of the abdomen (fig. 13). Both the head and the tip of the abdomen are bluntly rounded, giving the body a somewhat plump appearance. The size is variable, the length ranging from one-fourth to one-third of an inch. When at rest the wings lie flat, extending backward over the abdomen.

SEASONAL DEVELOPMENTAL HISTORY

These insects pass the winter as nearly mature larvae, more or less inactive, in the bulbs. As the weather becomes warmer early in the

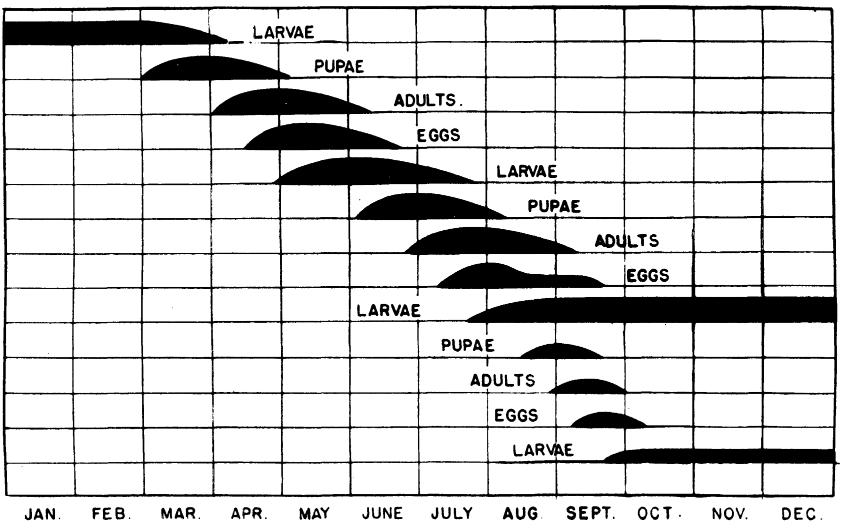

FIGURE 14.—Diagram of the seasonal development of the various stages of the lesser bulb flies.

spring the larvae become more active, feed to some extent, and migrate to the soil surface above. There they pupate, and 3 to 6 weeks later the adults emerge. The females lay the eggs in clusters of 3 to 10 or more in the soil close to or on the leaves at the necks of the bulbs. From these the hatched larvae work downward to the bulbs, which they enter and in which they develop. When mature, they move to the soil surface to pupate, and the adults emerge late in June or in July. These lay eggs, often on exposed bulbs in storage, from which a second generation develops. Most of the second-generation larvae remain in that stage through the following winter. A few develop to adults late in August or early in September. These adults lay eggs from which larvae hatch that pass the winter in a less mature condition than the second-generation larvae. The adults from both groups appear at about the same time in the spring. Thus there are two complete generations and a partial third annually, and

they overlap to a considerable extent. This development is represented diagrammatically in figure 14.

NATURE OF ATTACK

It is known that lesser bulb fly larvae are dependent on the presence of certain organisms for their proper development. In the absence of such organisms there is almost no growth of the young larvae. These associated organisms are not so likely to be present in a dry environment as they are in a moist one, and this may explain why dry bulbs in storage are frequently found with numerous eggs on the outer scales but perfectly sound and not suffering from any larval attack. Bulbs in which basal-rot organisms have begun to develop are particularly susceptible to attack, and most bulbs infested with lesser fly larvae are of this type. Bulbs injured by frost or other causes and bulbs infested by eelworms are also susceptible to attack. The feeding area of the larvae inside the bulb becomes moist and decomposed, and if the number of larvae is large the entire bulb soon becomes a mass of moist, rather slimy, decayed tissue through which the larvae squirm back and forth (fig. 10). The general appearance is very messy. The number of larvae in a bulb ordinarily ranges up to about 60, but occasionally many more are present. The largest number of larvae found in a single bulb was 947.

THE BULB MITE

Bulb mites (*Rhizoglyphus hyacinthi* Bdv.), usually associated with decayed tissue of some form, are likely to be encountered in almost any narcissus stocks. The white, shiny forms are conspicuous in the brown decayed tissue (fig. 15), and, because they are so prominent, growers are likely to blame them for the destruction of the healthy bulbs, although they are really secondary in their attack and are feeding on tissue already diseased or destroyed. Bulbs injured by mechanical means, rough handling, or heating, or weakened by disease are the types in which the mites are usually found. At times the mites are numerous in the dead outer scales of bulbs which are still moist, but these disappear as the bulbs become dry.

The adult mites are almost as big as the head of a common pin, round-bodied, glistening white, sometimes with a pair of dark spots on the back. The eight legs are reddish brown, with light-colored streaks at the joints, and the "beak," or mouth-part region, has a similar brown color. The ordinary immature stages are similar in color to the adults, but are smaller, and the first stage has only six legs. There is a special stage which appears in numbers when unsuitable environmental conditions are present. This is called the hypopus, and when it appears in the life cycle it develops from the first stage. This form is brown, somewhat shining, and turtle-shaped. It does not feed, it may live a long time, and it has a tendency to attach itself to active insects, such as flies, and is therefore a stage by which the mite is able to maintain itself through a period of unsatisfactory conditions and also to spread considerable distances.

Although the mite is considered secondary in nature, it is discussed here so that growers may realize that its presence is not necessarily a cause for alarm and that it may not be confused or mistaken for other pests.

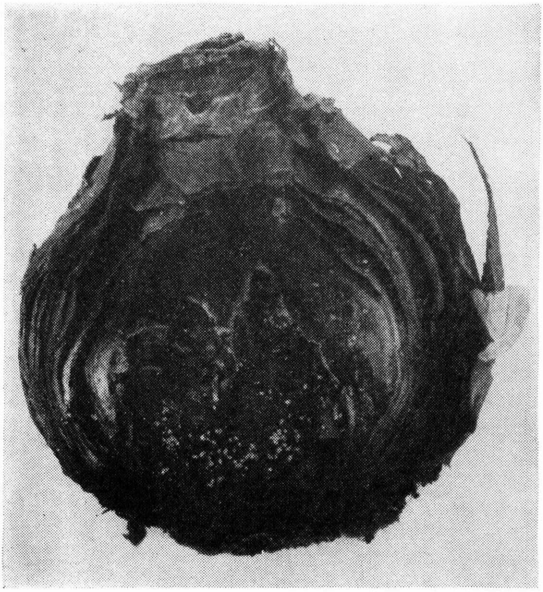

FIGURE 15.—Rotted narcissus bulb cut open to reveal bulb mites in the decayed tissues.

THE BULB SCALE MITE

In recent years a very small mite has been found infesting narcissus bulbs, and because of its habit of working between the bulb scales it is called the bulb scale mite. (This mite is now recognized as *Tarsonemus laticeps* Halbert; numerous published references to this mite have used the name *Tarsonemus approximatus narcissi* Ewing.) It is an entirely distinct form and should not be confused with the ordinary bulb mite.

The elongate bodies of the adult mites are only one one hundred and twenty-fifth inch long and hence are not discernible without the aid of a microscope or a strong hand lens. The adults are light tan colored. The white six-legged larvae hatch from the white oval-shaped eggs and develop to the mature condition, when they assume a quiescent form. During this quiescent larval stage, changes occur which are equivalent to those occurring in the pupal stage in insects, after which the eight-legged adult mites appear. The complete development takes place in the plant, and all stages are usually present together. Groups of considerable numbers on the bulb tissue have the appearance of fine grains of very light-colored sand.

Natural spread among growing bulbs is relatively slow, only a few feet in a season. Some artificial spread may be effected by cultivating tools, but this is probably not an important factor. However, in storage, where the bulbs are concentrated, the mites may easily spread to many bulbs, even though at the time of digging only a small number of bulbs may have been infested. Spread during the storage season is considered the most important type of dispersal of this pest.

Symptoms of feeding do not become readily apparent until the

populations in the bulbs become excessive, and consequently where cool growth conditions prevail the mites may escape detection for a long time. In temperatures below 60° F. the mites exist, but development is rather slow, and the populations in the bulbs remain at a rather low level, more or less stationary. In normal storage conditions the populations of mites usually increase to serious numbers by planting time, and these are largely concentrated in the areas of the bulbs where the new leaves and flower buds are developing. The feeding of the mites on this new growth causes a distortion of foliage and flowers which may reduce the quantity of flowers produced and distinctly lowers the quality of those that do develop (fig. 16).

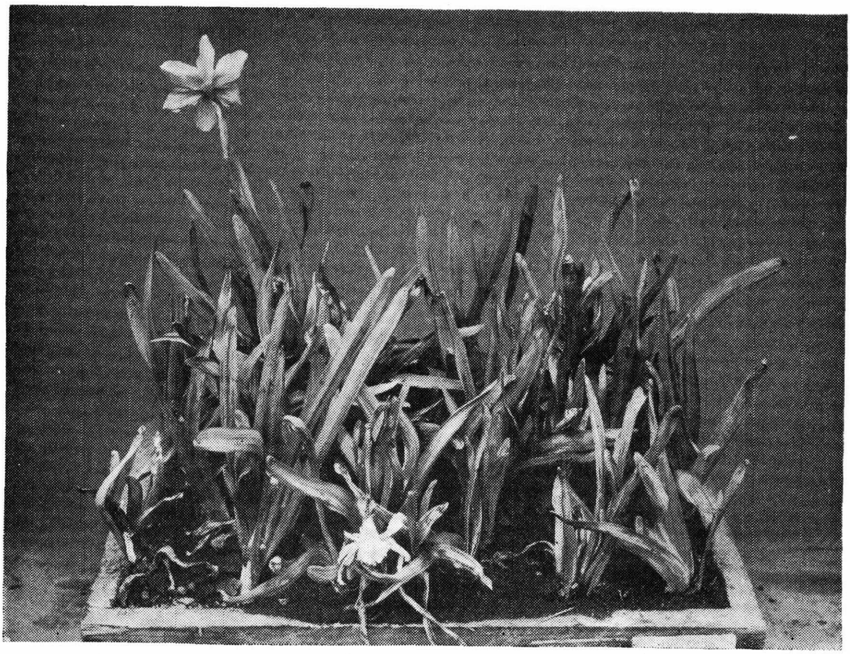

FIGURE 16.—Heavy infestation of the bulb scale mite, causing severe distortion, stunting, and failure of blooms in forced narcissus bulbs.

The typical indications of bulb scale mite attack, in addition to distortion, are scarlike, yellowish-brown, longitudinal streaks on the leaves or the flower stem. Short transverse cracks are often present in the scarred areas, and distortion and twisting of varying degrees are usually associated with the scarring, as growth in the injured areas is not so rapid as in normal tissue. Where infestation is light a slight twist of the flower stem may be the only evidence of the mites.

On stored bulbs there are no external indications of the presence of these mites. Infestation within the bulbs is evidenced by moderately dark yellowish-brown areas on the normally white scale tissue. Usually these areas are in places where there is a natural slight separation of the scales (fig. 17). The discoloration is best observed by cutting the bulb from neck to base and separating the scales and shoots.

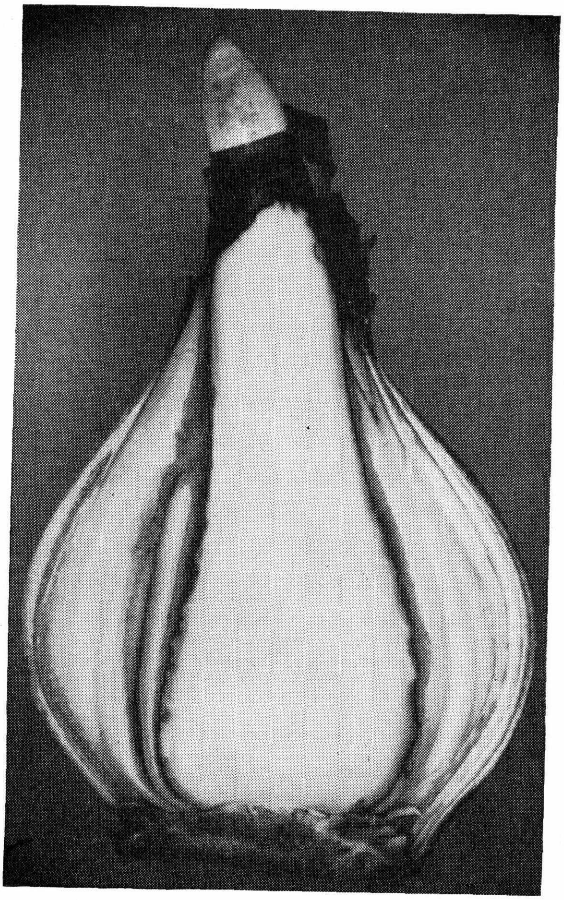

FIGURE 17.—Feeding of the bulb scale mites within the narcissus bulb, causing a discoloration of the bulb tissue. This discoloration is most pronounced on the edges of the developing shoot of the bulb.

METHODS OF CONTROL

Control measures are of two general kinds, (1) field treatments, intended to prevent attack by the bulb flies, and (2) storage-season treatments, utilized to kill the pests that may be present in the bulbs. Measures employed to reduce or eliminate rots and injuries of any kind may be considered as indirect aids in controlling lesser bulb flies, and they also assist in reducing the populations of bulb mites.

No really satisfactory field treatment for bulb flies has been developed. In England poisoned-bait sprays have been recommended, but these appear to be ineffective under conditions in the United States. Moderate plantings of bulbs of more than ordinary value may be economically protected by constructing temporary cages (fig. 18) over the plants to prevent the adult flies from gaining access to the bulbs. Such cages may have cheesecloth sides, but tops made of wire screen (12-mesh) are preferable because they do not interfere

so much with the passage of sunlight and rain. Cage protection is needed only during the period of fly activity. This normally comes after the blooming period is passed for all except extremely late varieties; hence the use of cage protection does not interfere with the enjoyment of the flowers.

Storage-season treatments include fumigation with hydrocyanic acid gas (HCN), which is effective only against bulb fly larvae, and heat treatments, which are effective against all the pests in the bulbs.

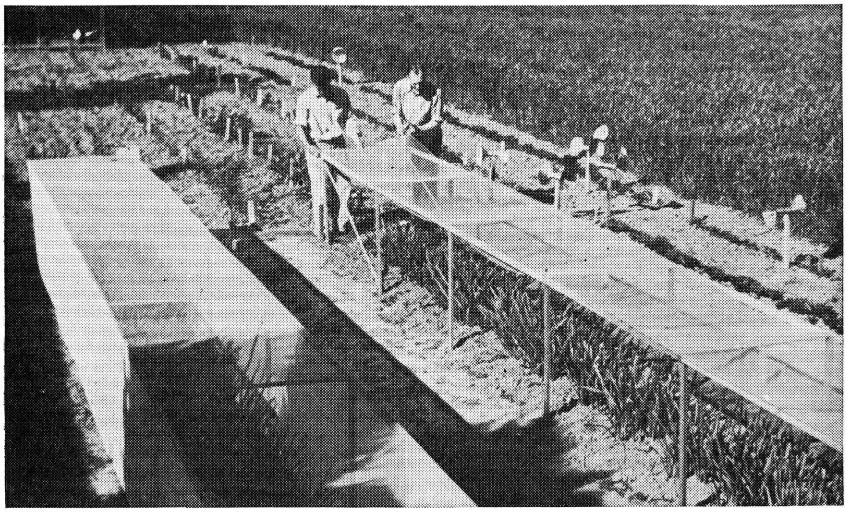

FIGURE 18.—Temporary cages over narcissus bulbs to protect them from the attack of the narcissus bulb fly. Wire screen for the top and cheesecloth for the sides are economical and easy to put on a frame of light lumber.

HYDROCYANIC ACID GAS FUMIGATION

Fumigation with hydrocyanic acid gas is effective in killing the bulb fly larvae within the bulbs. In order that sufficient gas may penetrate into the bulbs and reach the larvae it is necessary to use a rather strong concentration in the fumigation chamber. Stored narcissus bulbs are able to stand the heavy concentrations of the toxic gas without being detrimentally affected.

Caution: It should be recognized that sodium cyanide, calcium cyanide, and the hydrocyanic acid gas (HCN) evolved from them are all deadly poisons. Adequate precautions, including the use of properly equipped gas masks, should be observed in using the gas and the materials from which it is generated. Fumigations should be conducted only by experienced and dependable persons. The fumigation chamber should be cleared of all residual gas after fumigation, before anyone is allowed to enter. It is not advisable to handle fumigated bulbs (in grading, counting, etc.) until at least 24 hours after they have been removed from the fumigation chamber.

Either granular calcium cyanide or sodium cyanide may be used as the source of the gas. A reaction of the calcium cyanide with atmospheric moisture evolves the gas. This reaction is rather slow, and the chemical must be spread out thinly to permit the air to reach

all of it. It is best applied by being spread on papers on a shallow pan or tray which is placed on the floor of the fumigation chamber. At the end of the fumigation the spent material may be rolled up with the papers and easily disposed of. For bulb fly larvae, granular calcium cyanide should be used at the rate of 16 ounces for each 100 cubic feet of space, and the period of fumigation should be 4 hours.

If sodium cyanide is used, it must be placed in a dilute solution of sulfuric acid in order to generate the hydrocyanic acid gas. Sodium cyanide is obtainable in the form of balls which weigh either one-half ounce or 1 ounce, so the proper amount needed is easily obtained merely by counting out the balls. The proportions of water, sulfuric acid, and sodium cyanide are as follows:

Water	3 fluid ounces.
Concentrated sulfuric acid	1½ fluid ounces.
Sodium cyanide	1 ounce (by weight).

A container which will withstand heat and acid is required, and it should be oversize, that is, sufficiently deep to prevent splashing over, because the reaction of the mixture is accompanied by a rather violent "boiling." The water is placed in the container first, then the acid is poured into the water slowly, and when everything else is in complete readiness for the fumigation to begin, the sodium cyanide is dropped into the water-acid solution. The reaction of the sodium cyanide with the dilute acid is immediate, and it is advisable to arrange the generating apparatus in such a way that the sodium cyanide may be dropped into the liquid after the fumigation chamber is tightly closed. This may be done by a chute, a pivoted shelf, or some other type of holder that can be operated from outside the chamber. All the gas is generated in a few minutes. For bulb fly larvae, 7 ounces of sodium cyanide, with the proper quantities of sulfuric acid and water, are used for each 100 cubic feet of space, and the duration of the treatment should be 4 hours.

The primary necessity for successful fumigation with hydrocyanic acid gas is a tightly constructed chamber. Tightness is essential to maintain an effective concentration of the gas throughout the duration of the fumigation. Complete plans for the construction of fumigation chambers are not presented, because any chamber should be built according to the individual needs and circumstances. Size would naturally vary according to the quantity of bulbs to be treated, and the dimensions should be adapted to the size of the bulb tray used and the method of loading. Several types of construction have been found entirely satisfactory (fig. 19). A number of chambers have been made of two layers of tongue-and-groove knot-free lumber (flooring type), the inner layer horizontal, the outer layer vertical. An elastic, puttylike material is placed in the grooves as the boards are assembled, and when the tongue of the adjacent board is forced into this material it forms a very tight joint. Building paper is used between the two layers to aid in making the construction as tight as possible.

Several chambers have been constructed of plywood (veneer) panels (fig. 20). These are erected vertically to form the walls and are matched across the top. The floor is made of a layer of regular flooring on a sublayer of fairly heavy boards. The joints of the panels are made tight by painting the surfaces, both inside and outside, with

thick asphalt paint, and an overlapping strip of wood is placed on each side. The panels are fastened together with carriage bolts the tightening of which squeezes the pieces of plywood tightly together, and the asphalt paint completely fills all the crevices. In some chambers of this type strips of felt soaked in asphalt paint have been laid over the joint before the overlapping strips were placed. In constructing these joints the most satisfactory method has been to use 2- by 4-inch wood for the outside of the walls, 1- by 4-inch for the inside, and 1- by 4-inch for both the inside and outside of the top joints.

Sheet metal (galvanized iron) may be used with a framework of 2- by 4-inch lumber to furnish rigidity. All joints of the metal must be soldered. Some fumigators of metal construction are raised and lowered by block and tackle over the stacked bulbs to be fumigated.

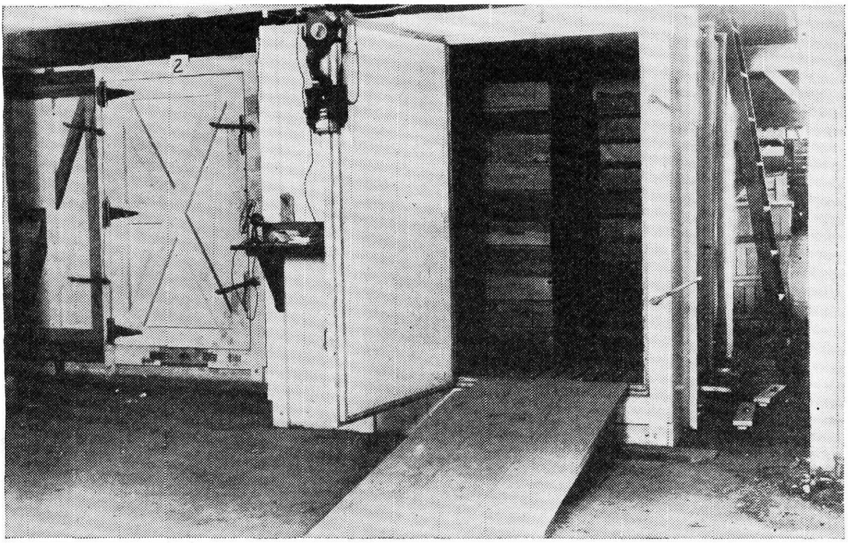

FIGURE 19.—Fumigation chamber used for narcissus-bulb fumigation. The stacks of bulb trays rest on a false slat floor, under which long trays containing calcium cyanide are pushed from the side of the fumigator.

These, of course, have no door, the edge of the metal chamber being lowered into a narrow trough filled with oil to make an airtight seal. A more or less square floor plan is most practical for this type. The bulbs are stacked on a special tight platform with a raised false floor. The oil-filled trough is fastened to the edge of the platform. Some growers use two such platforms and use the metal chamber alternately on these, removing the treated bulbs and preparing a new load for treatment on one platform while those on the other platform are being fumigated.

A suitable method for testing the tightness of a fumigation chamber is to burn a short piece of automobile inner tube within, with proper protection to avoid fire. The resulting smoke will work out of any leaky places, and these can be marked and fixed.

Although in some instances circumstances may indicate otherwise, the general experience of the bulb industry indicates that an oblong

chamber is most effective, with one entire end used for the door. In this way the framework for the end also serves as a strong surface against which the door can be closed with pressure. Angle iron has been found advantageous in the construction of the door frame, as it will stand excessive wear and tear and much bumping without getting out of shape. Two seating surfaces around the edge of the door are advisable, and rubber stripping on these seating surfaces furnishes a tight seal when the door is closed. Refrigerator-type hinges and clamps should be used for the door.

Untreated wood surfaces absorb considerable hydrocyanic acid gas, and to reduce such absorption to a minimum the interior of the

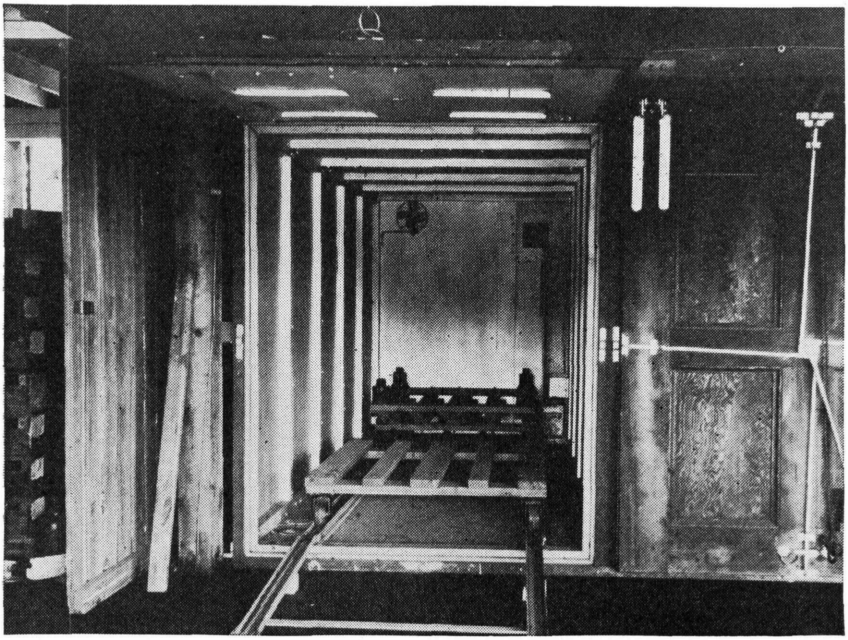

FIGURE 20.—Fumigation chamber used for narcissus-bulb fumigation. The door hinges are at the top, and the bulb trays are stacked on small cars, which are pushed into the chamber on a track.

fumigation chamber should be painted with aluminum paint. This increases the efficiency of the gas.

The bulbs to be fumigated should be not more than three layers deep in slat- or wire-mesh-bottomed trays. Also the bulbs should be reasonably free from soil and fairly dry. The fumigation chamber should not be loaded to more than 75 percent of its capacity. There should be a false floor on which to stack the bulb trays, or else the bottom tray in each stack should be empty. If calcium cyanide is used, the false floor is necessary. These conditions are essential to permit the fullest possible circulation of the gas throughout the bulbs. The temperature of the bulbs should be above 60° F. when they are fumigated. A circulating fan inside the chamber is essential to prevent possible pocketing of the gas. The preferable method of exhausting the gas is the use of an exhaust fan built into the fumigator wall.

If only a few bulbs are to be treated, a small box may easily be constructed to accommodate a single stack of five or six trays. For this a framework of 2- by 2-inch lumber is made, and then plywood sheets are fastened inside to form the sides and top. A double thickness of the plywood or heavier lumber may be used for the floor. An entire side is used for the door, and for this opening a piece of plywood with a frame of 2- by 2-inch material is used. A fumigator of this type is adapted to the use of calcium cyanide. This material is spread on a flat, shallow pan, which is pushed under the stack of bulb trays, and then the door is placed in position and fastened tightly by means of clamps. A diagram of such a box is presented in figure 21.

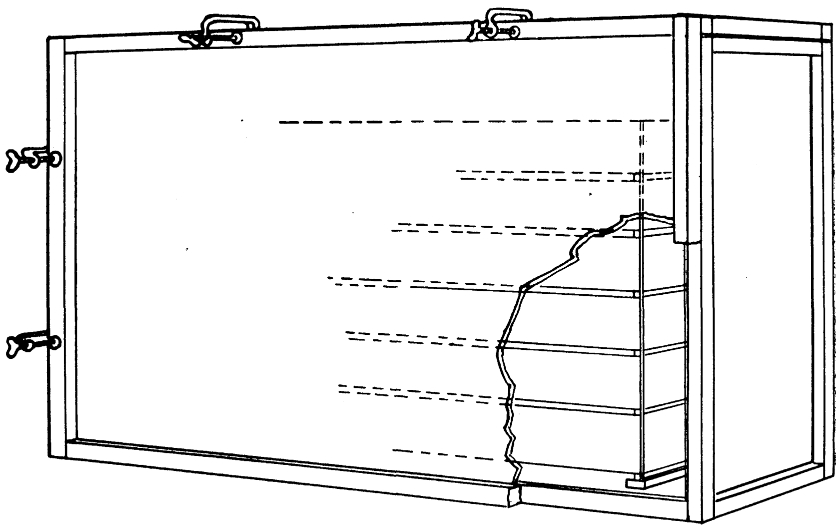

FIGURE 21.—Diagrammatic view of a small fumigation box in which calcium cyanide may be used as a fumigant.

HOT-WATER TREATMENT

Immersion of narcissus bulbs in hot water for definite periods is a treatment completely effective against bulb fly larvae, the bulb mite, and the bulb scale mite. This method has been widely adopted by narcissus growers for the control of eelworms (nematodes), and a treating temperature of 111° F. is generally accepted as standard. The present accepted treatment for eelworm control includes a preliminary 2-hour soaking of the bulbs in water at 70° to 80° F., after which the bulbs are placed in water at 111° F., and after the bulbs reach 111° they are maintained at that temperature for a 4-hour period. Formalin, at the rate of 1 pint to 50 gallons of water (1–400 dilution), is generally used in the treating water. Such a treatment is much more prolonged than is needed for bulb fly larvae, bulb mites, or bulb scale mites. The presoaking is needed only for eelworm control, as its purpose is to activate quiescent eelworms. The formalin is used to increase the efficiency of the treatment in killing the more resistant stages of eelworms that might be present. A

total immersion period of 90 minutes (1½ hours) at 111° is sufficient to kill bulb fly larvae and all stages of the two kinds of mites found in narcissus bulbs.

Caution: Some people are particularly sensitive to formalin. Handling it entails some danger, and care should be taken to avoid getting it on the skin and to avoid inhaling its vapor.

Commercial growers use rectangular-shaped tanks, heat the water by means of steam passing through coils on the tank floor or injected directly into the water, and circulate the water by means of a motor-driven propeller. The bulbs are handled in rigid containers of heavy wire mesh on angle-iron frames or in the standard type of crate used for shipment (fig. 22). A frame or false bottom keeps the

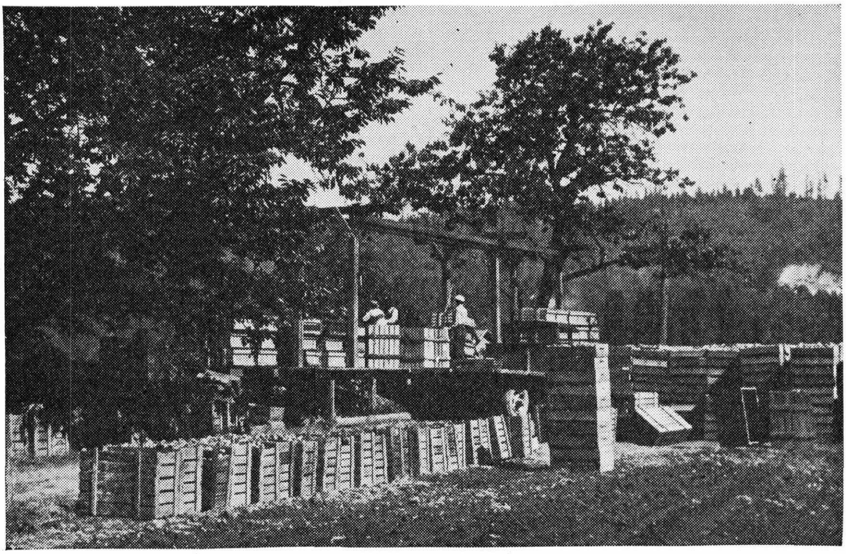

FIGURE 22.—Narcissus bulbs being loaded into cases for hot-water treatment.

load far enough above the tank floor to permit the water to circulate under the load. Direct introduction of steam into the water, controlled by a hand valve, is the generally preferred method of operation, because it permits rapid heating and is relatively simple to construct and operate. The propeller is placed just above the tank floor in the center of the tank end, the shaft extending through a marine-type stuffing box to the outside, where power is applied. The propeller forces the water along the bottom of the tank under the load to the opposite end, where the water rises and flows back through and around the load. The steam outlet is placed just above the propeller, the pipe leading down just inside the tank. This permits the steam to become mixed immediately with the circulating water, and there is no overheating of any part of the mass of water.

Water tanks of various sizes are in use. The construction may be of either wood or steel. Wooden tanks may be built of tongue-and-groove planking calked for watertightness. Steel tanks are made of heavy sheet steel with welded corners, and an angle-iron facing around the top edge adds rigidity and strength.

When only a few bulbs are to be treated it may be practical to use a washtub or similar container, handling the bulbs in open-weave sacks (onion type) or in cheesecloth sacks. The bulbs should be loose in the sacks and the sacks placed loosely in the container, for in the absence of mechanical agitation the water must be stirred by hand frequently, and the loose packing is needed to permit suitable circulation of the water. The water temperature should be 113° or 114° F. when the bulbs are immersed. The warming of the bulbs will reduce the excess temperature to the desired temperature, 111°, and it may be maintained at this point by the addition of small quantities of hot water (150° to 180°) at frequent intervals. At ordinary summer air temperatures additions of about 1 pint of water at 180° at approximately 10-minute intervals will maintain the water at 111° with not more than 1° of variation above or below. It is necessary to stir the water frequently to equalize the temperature throughout the whole container.

Whatever type of equipment is employed, it is absolutely essential that an accurate thermometer be used to determine the water temperature. The thermometer must be of a type made for use in warm or hot water and should be graduated in single degrees.

Narcissus bulbs should not be treated when there is any evidence of sprouting roots or leaf tips, as injury to them may result. The most desirable time to subject narcissus bulbs to hot-water treatment is 3 to 4 weeks after digging, assuming that the bulbs are dug at the normal season, shortly after the drying of the foliage. If any considerable time is to elapse between treating and planting, special attention must be given to the drying of the bulbs after treatment. Just as soon as possible after the bulbs are taken out of the water they should be removed from the treating containers and spread out thinly where they can dry rapidly.

VAPOR-HEAT TREATMENT

Another means of storage-season control is the vapor-heat treatment. This is completely effective against bulb fly larvae, bulb mites, and bulb scale mites. Heat is used as the killing agent, and the bulbs are heated by supersaturated warmed air, which is circulated through the bulbs in stacked trays and maintained at the desired temperature by steam and water sprays. In its circuit through the equipment the air is moved through a conditioning apparatus containing steam and cold-water sprays, which are adjusted to maintain the heat of the air at the desired temperature and to saturate it with water vapor. The bulbs become heated to the desired temperature, which is maintained for the time required. For bulb fly larvae, bulb mites, and bulb scale mites a 2-hour treatment at 111° F. is recommended, this period beginning after the load becomes heated to that temperature. The most desirable treatment season is the same as for hot water.

Since equipment of this type is intended primarily for large-scale operations, it is suggested that anyone contemplating its use communicate with the Bureau of Entomology and Plant Quarantine for advice concerning the suitability of its installation under the conditions involved.

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